235

Conference

S60-5

S1326-0001

RECORDED

Proceedings of the 6 International Aerospace instrumentation Symposium Cranfield, Beds, England. (23-26 March 1970)

DEVELOPMENTS IN AIRBORNE CRASH RECORDERS

Claude Vatinelle
Société d'Instrumentation
Schlumberger,
Paris,
France.

GENERAL

After an aircraft crash, it is necessary, in order to make the enquiries easier, to have access to the evolution of the principal parameters.

Whether it is a military plane or a civil plane, the recording time varies from 30 minutes to 25 hours. The information support being replayed theoretically only after an accident, it is the total parameters inscription possibilities which has to be permanently captured in memory. Therefore, it is interesting to record the verbal communications of the technical crew.

Such a recording system is composed of :

a) The parameters transducers and verbal commentaries.

b) An electronic unit composed of :
   - the signal conditioning circuits fed by the transducers
   - the multiplexing circuits for the cyclic and successive strobing of these signals
   - a control logic for multiplexing circuits and clock pulse generation.

c) a recorder including its own writing circuits for the parameters on a memory protected against the environmental conditions, corresponding to a crash.

For obvious reasons, no equipment standardization exists for crash recorders to be mounted on military aircraft. On the other hand, the international airlines, the regulating boards for civil aviation, aircraft manufacturers and equipment manufacturers have joined their efforts to define an equipment acceptable to the greatest number, the aim being to allow equipment interchangibility.

Diagram No.1 has outlined the philosophy of such an accident parameters recording system and its possible extension for eventual maintenance purposes.

This paper does not pretend to discuss this diagram nor to enter into details concerning the type of parameters to take into account or the data acquisition.

Among the recorders noted, two already follow a standard : the Cockpit voice recorder (CVR) and the Digital flight data recorder, the maintenance recorder only representing an actual commodity.

The Cockpit voice recorder is defined in detail in ARINC document 557. It records on 4 tracks the verbal communications of the technical crew and the sounds captured by a cockpit microphone. Its running time is 30 minutes ; it possesses the necessary circuits for checking its normal functioning. It can also receive a coded message, recorded in FSK on one of the voice tracks.

This type of recorder, well known at the present day, needs no special comment.

The digital flight data recorder has to record at least the last 25 hours of a certain number of parameters presented by the output of the flight data acquisition unit as a serial message 64 x 12 bit words per second.

The system defined in ARINC 573 allows the use of several data acquisition units and auxillary data acquisition units, thus permitting through a data management unit, recording of the necessary parameters for aircraft maintenance purposes.

PROTECTION OF THE RECORDED MESSAGE

In the system described above, it is only the support containing the main parameters evolution for the length of time desired, which has to be saved after a crash for its analysis.

Accident recorders, to be so considered have to successfully survive several tests that one thinks representative of what can occur during an aircraft crash. Although, military and civil standard tests are different, tests to evaluate the resistance of accident recorders to aircraft crash environment are mainly contained in technical orders TSO C51 a. The crash survivability portion is as follows :

1) Half-sine wave impact shocks applied in each of the three main orthogonal axes, and having a peak acceleration magnitude of 1000 g with a time duration of 5 milliseconds.

2) Statis crushing force of 5000 pounds, applied continuously but not simultaneously to each of the three main orthogonal axes for a test period of 5 minutes.

3) An impact shearing force, equal to a 500 pounds steel bar which is dropped from a height of 10 feet to strike each side of the enclosure. The point of contact of the bar shall have a cross sectional area that is no greater than a cylindrical rod one-fourth inch in diameter. The longitudinal axis of the bar

4) An exposure to flames of open fire at 1 100°C for a continuous and uninterrupted period of 30 minutes in which the flames envelop at least 50 per cent of the outside area.

ACCIDENT RECORDER DESIGN

It is in view of the survival tests that the principal options for the design of an accident recorder are taken. The main recording medium commonly used react differently and it is interesting to compare briefly their relative merits.

To a shock impact, magnetic tapes with plastic base appear to present the most interest because they present a low masse to internal acceleration forces. They are flexible and recover their shape allowing a normal restitution of the message.

Wires have a high tensile strength, discs and metal tapes are more vulnerable because of their mass.

A penetrating element in the recording medium due to a shock will cause more damage to the medium having the highest information density. Discs and wires are therefore more vulnerable.

To heat exposure, stainless foils and aluminium foils present the best reaction. They can be respectively exposed to temperatures of 1100°C and 650°C without data loss.

Magnetic tape using a Kapton base or Mylar base are the least resistant. They can only be exposed to 400°C and 250°C ; - above these temperatures, their bases melt. The conclusion is that, with an exception for the stainless foil, direct exposure of all the other medium to a 1100°C temperature will destroy the data.

Basic options have to be taken also in regard of the operational point of view.

Although the data occupation factor is better on wire than on tape, tape handling is more practible. Minimum cost is also of concern and magnetic tape with its wide development presents the cheapest solution.

Design of the enclosure in regards of the best strength presented would lead to a sphere or a spheroid shell, but this solution is not the best in regards of the volume occupied. As a matter of fact, the minimum volume required for a recorder using such a shell leads to a diameter larger than the standard ATR height.

On the other hand, to achieve the same protection with a parallelepiped box leads to an increase in weight.

REALISATION

The accident recorders we developed were designed after having retained a certain medium and a certain type of fire protection as main options.

MAGNETIC TAPES RETAINED

Two types of tapes have been retained :

. ...ical oxide tape

backing (Kapton), coated with a 7 micron magnetic layer, developed by PYRAL.

- Backing properties :

The polyimide tape keep its physical properties up to 250°C without any notable deterioration and, in particular, without an important residual elongation, 0.3% at 250°C. Moreover, it is non-inflammable and inert.

- Tape properties :

- Thermal properties : the realized magnetic tape can be stored up to 130°C for, at least, one hour without any magnetic or physical property deterioration. Tapes tested at 800 and 1600 bpi have been tested again after spending one hour at 130°C, reeled with a 200 g tape tension and no failure has appeared after this process. The recorded data is entirely replayed.

- Behaviour with chemical agents : the tape is not deteriorated by water and is insensible to petrol.

- Life : the tape enables 10,000 passes at 3m/sec., with a 300 g tension, without error. It is certain that with a lower tension and a very much lower speed, this figure would be considerably increased.

B - Metallic tape

This tape is made of a 23 micron polyimide backing which is coated with a 2/10 up to 3/10 micron thickness metal layer. This layer is sufficient to give a signal as large as a 7 micron classical tape.

The constitution of such a tape enables the recording of extremely high densities up to 16,000 fcpi, with well fitted heads and may lead, in particular, to the realization of very low speed tape recorders. Moreover, at 3,200 fcpi, there are no pulse crowding problems.

- Thermal properties : these tapes are specially manufactured in order to allow storing up to 250°C without attenuation of the play-back signal. No information loss appears after storage for one hour at 250°C.

- Behaviour with chemical agents : the metallic tape is insensitive to water, oil and solvents.

- Life duration : the realization of a tape including a very hard and slippery overlayer has been undertaken, i.e. reduces slightly the electro-acoustic performance (12,000 fcpi accessible densities) but considerably increases the number of passages without error, typically, 5,000 passes on a normal tension tape recorder. This service life could be in the near future, the same as that of the classical tapes.

FIRE PROOFING

The recorder is so conceived that the recording remains unaffected in the following conditions :

- exposure of, at least, 50% of the outside surface, to a flame of 1100°C for 30 minutes.

The solution taken up by SIS consists of inserting between the enclosure holding the tape transport, and the outside enclosure, an ablative material (patented) using a highly endothermic reaction, to project the tape.

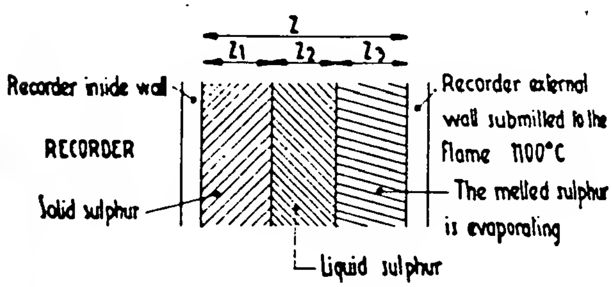
The principle used consists in the exploitation of physical properties of two elements : sulphur and vermiculite.

Sulphur is used for its temperature and its latent heat of melting and evaporation (115°C and 444°C).

Vermiculite is used for its low calorific transmission power.

The sulphur and vermiculite assembly is agglomerated with cement powder mixed with water. The material thus obtained acts in the following manner. Referring to the diagram, Z is the mixing layer between the two walls.

In a first step, the heat on the outside wall makes the temperature rise inside.



The temperature of the material is obviously different if one considers the Z1 or Z2 or Z3 area (see diagram). Thus, the temperature will reach the melting temperature in Z3, whilst Z2 will begin heating. In the same way, when the sulphur is melting in Z2, Z1 will start heating, and the temperature in Z3 will be so high that the evaporation level will be exceeded.

Of course, the Z3, Z2, Z1 areas necessary for explanatory purposes are purely arbitrary and serve only to materialise the heating process of the required temperature at a certain time.

Therefore, as long as there remains solid sulphur in Z3, the temperature in this area is less than 114.5°C.

As long as there remains liquid sulphur in Z3, the temperature in this area is less than 444.5°C.

When the temperature in Z3 reaches 444.5°C, the sulphur evaporates.

Thus, proceeding in order, a temperature rise succeeds a change in state which, absorbing calories, constitutes a stage, the change in state being made at a constant temperature.

The temperature rise and, above all, the advance from on area to the other is slackened by the presence of vermiculite which acts like a screen.

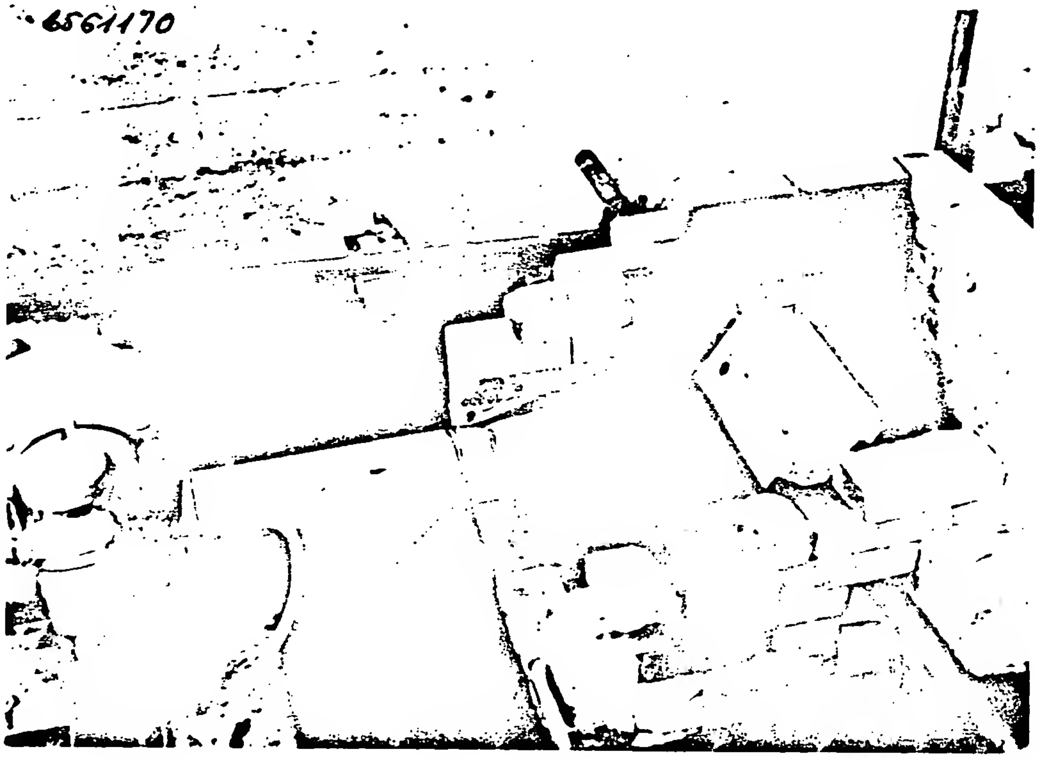
Moreover, sulphur, whatever the state, remains in its initial place, due to the use of cement.

So, the protection is effective throughout the volume occupied by the material.

The material also contains water, the evaporation heat of which intervenes also in the heat absorption.

The choice of basic elements (sulphur) is dictated by the required maximum temperature (in our case approx 110°).

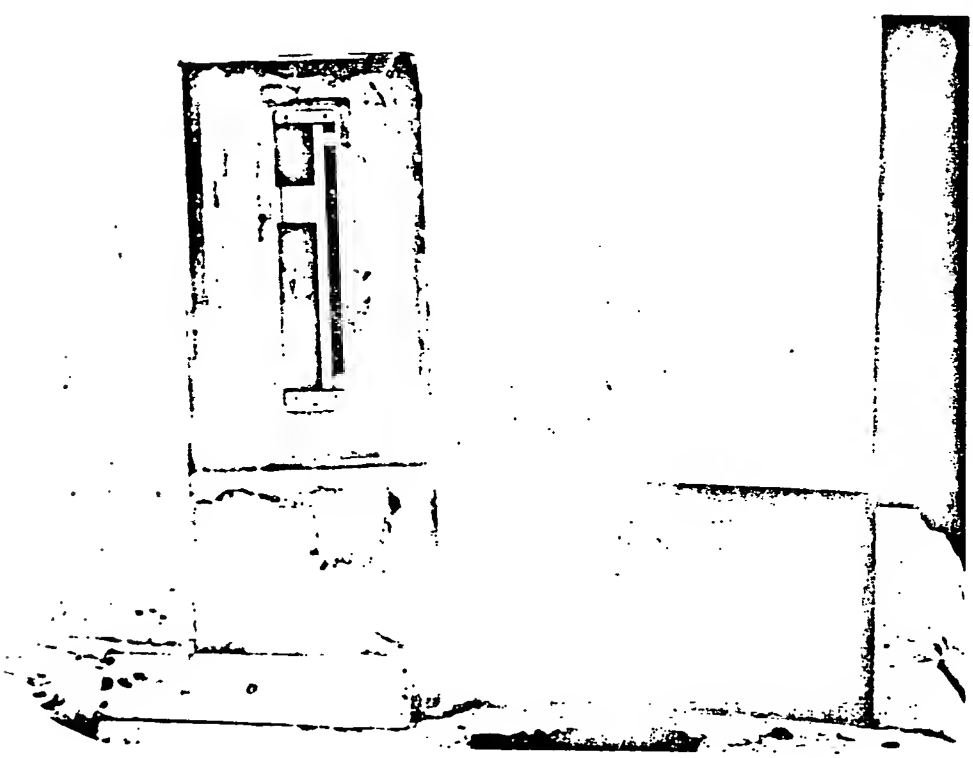
6561170



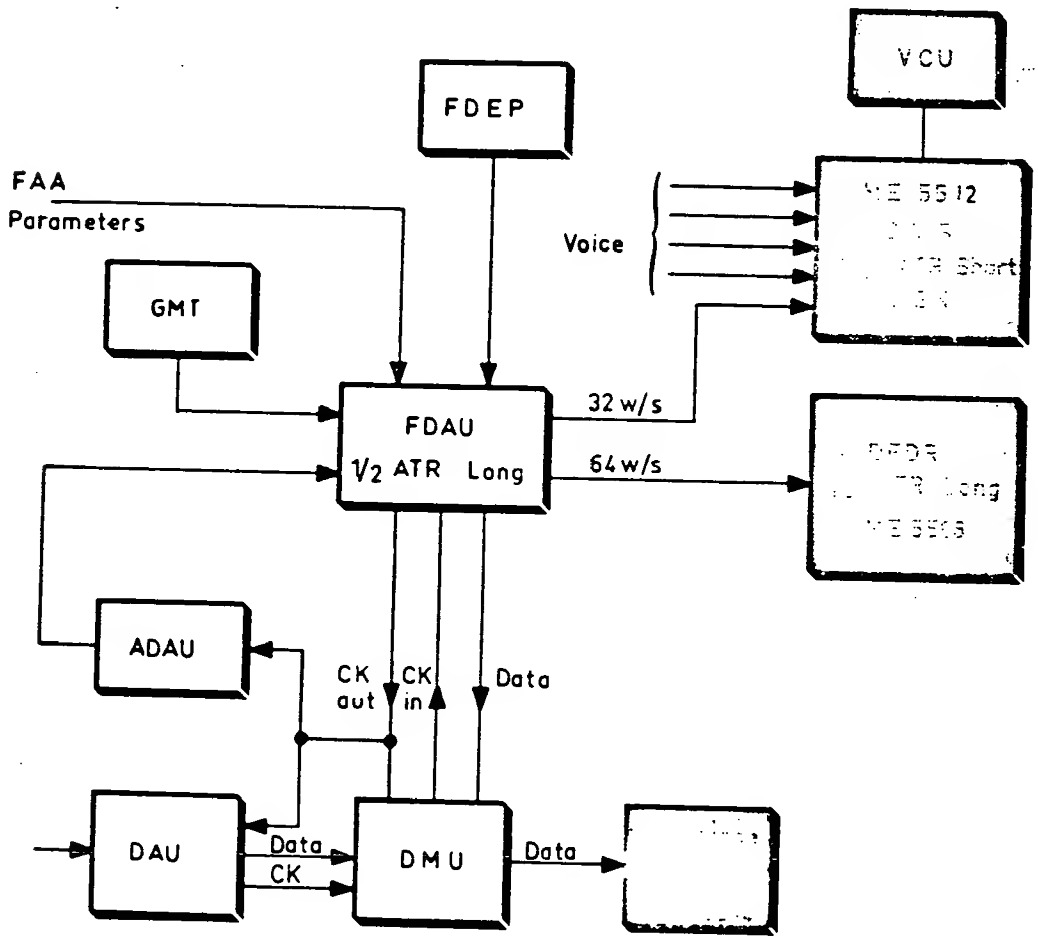
Recorder on bench before the test

6561112

Recorder on bench after the test



S1326-0001



ACCIDENT AND MAINTENANCE RECORDERS

SOME SIS DEVELOPMENTS

DFDR

The digital flight data recorder ME 5508 is a subsystem of the EFDARS ARINC 573 data recording system.

This recorder uses the well developed techniques of Schlumberger recorders ; it follows strictly the ARINC 573, TSO C 51 A and RTCA DO 138 specifications and standards.

The recorder, as prototype, will be mounted on the first BOEING 747 of AIR FRANCE and has been chosen by Avions Marcel DASSAULT for the first MERCURE Aircraft.

Design principle :

The DFDR type ME 5508 records on a magnetic tape, the last 28 hours of recorded data, and survives aircraft crash conditions.

The recording support, a ½" tape using Kapton, is mounted in an easy access cassette.

The recorder is designed to offer a high level of protection for this tape in case of crash and a high reliability in normal working conditions.

Description :

The ME 5508 is housed in a ½ ATR long case divided in two sections :

- the tape deck (except the motor) located in the protected area,
- the electronics including the power supply, tape transport control, the synchronous motor, the record and replay amplifiers.

The tape deck :

a - Protected housing :

It consists of :

- an external case using titanium metal
- an internal case using titanium metal
- in between, an endothermic sulphur material already described.

b - Tape transport :

The tape transport is located inside the protected area and includes :

- the cassette with its two reels allowing a capacity of 160 meters of ½" tape
- the two pinch rollers
- one 16 track magnetic head

c - Motor and servo system :

The synchronous motor located outside the protected area drives the capstans via gearing.

The tape speed is : 1"/s.

Both capstans are driven in opposite directions.

Each pinch roller is controlled by a mechanical cam.

This system connected to the cycling commutator (forward/reverse motion), allows by a gearing device, the transport of the tape in one direction or the other.

d - Electronics :

The electronics are located, like the motor, outside the protected area.

Rate : the data input rate can be 1600 bits/second with a maximum bit density of 1600 bpi.

Format : recording is made by saturation of the tape with the biphase code allowing self clocking of the message.

Amplifier : only one record amplifier is used. The biphase signal which comes from the FDAU is reshaped before entering the record head circuit.

Track commutation :
The commutation of the tracks is made by an electromechanical device. The commutation order is given by the cycling system. In the absence of power, the electromechanical device remains in position. There is no erasing track by track before the recording, since the recording is made by saturation of the tape.

Checking :
The checking of the recording is made by a systematic reading of the first track, and by "echo-check". The clock is taken out from the biphase signal ; an electronic circuit detects the rate variation of the clock which could occur with an irregular tape motion.

Technical data :

Mechanical

Titanium structure : light alloy material

Size : $\frac{1}{2}$ ATR long

Weight : 10.6 kg with AV mounting

Power supply : 115 V 400 Hz

Protection against : Shocks, Fire, Static crush, Fluid resistance } as specified by TSO C 51A

Tape transport

Continuous speed : 2.54 cms ; 1"/s.

Duration : 28 h

Tape (Cassette)

Length : 160 m.

Width : $\frac{1}{2}$"

Thickness : 35 μm

Type : Pyral (support Kapton)

Electronics

Continuous recording

Tracks : 16 commutated one by one

Input bit/rate : 64 words/sec.

Input format : biphase (Harward)

Input level : - 5 to + 5 V

MAINTENANCE RECORDER

- Design principle

The maintenance recorder type ME 5514 memorizes on a magnetic tape the last 75 hours of recorded data.

The recording support, a $\frac{1}{2}$" tape using a Kapton support, is mounted in an easy access cassette.

- Description

The ME 5514 is housed in a $\frac{1}{4}$ ATR short case. The tape deck with the driving motor, the electronics including the power supply, tape transport control, record and replay amplifiers, slide on rails when the front of the recorder is pulled, giving rapid access to the tape cassette.

- Tape transport

The tape transport includes :

- The cassette with its two reels allowing a capacity of 340 meters of $\frac{1}{2}$" tape
- The two pinch rollers
- One 16 track magnetic head.

- Motor and servo system

The synchronous motor drives through gearing, the capstans.

The tape speed is : 20 mm/sec.

Both capstans are driven in opposite directions.

Each pinch roller is controlled by a mechanical cam.

This system connected to the rotating commutator (forward/reverse motion), allows by a gearing device, the transport of the tape in one direction or the other.

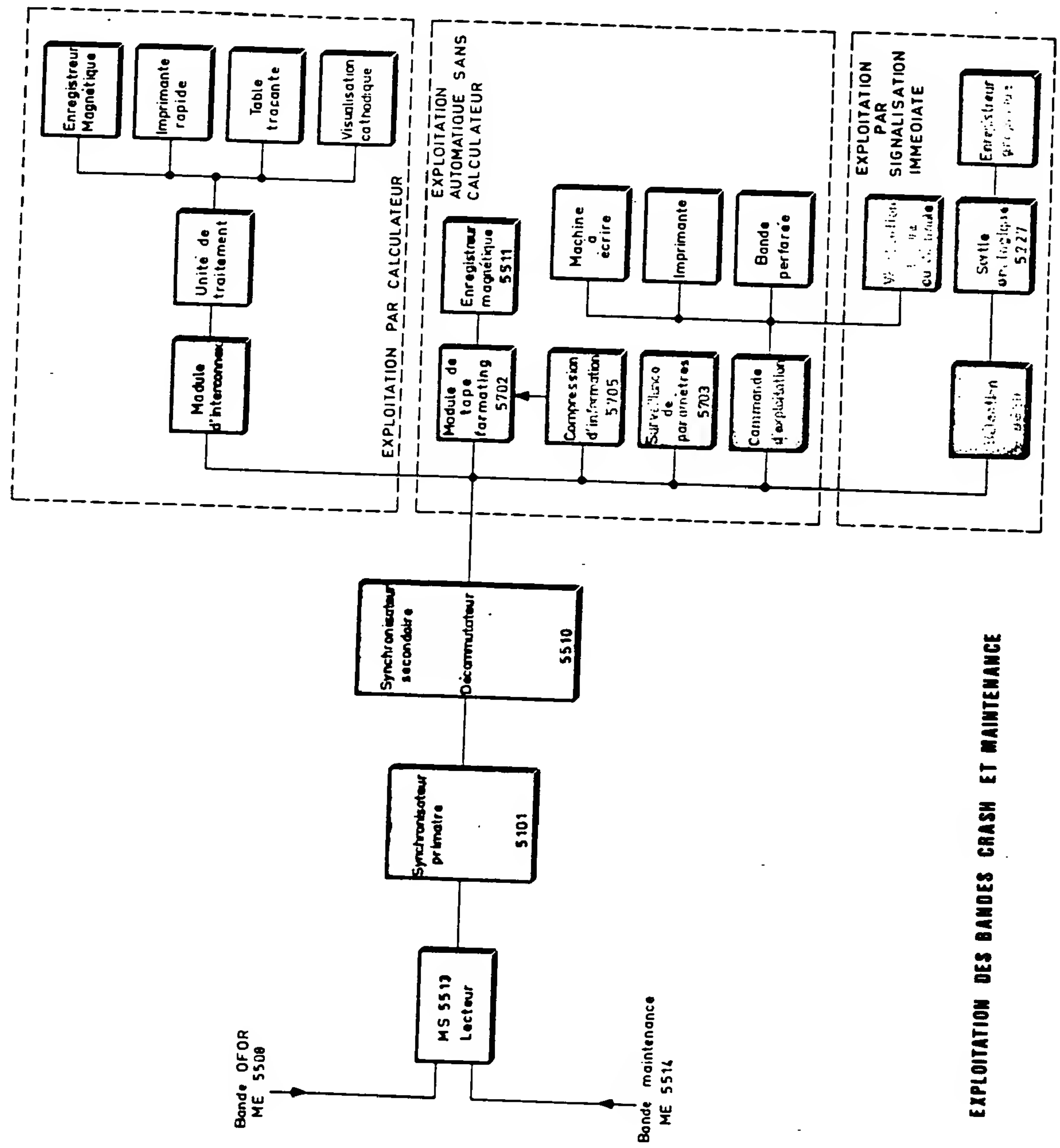
- Electronics

The electronics, located above the tape transport, is connected to the output plug by means of a flexible flat cable.

- Tape format : recording is made by saturation of the tape with the biphase code allowing a self-clocking of the message.
- Amplifier : only one record amplifier is used. The biphase signal which comes from the FDAU or the ADAU or the DMU is reshaped before entering the record head circuit.
- Track commutation : the commutation of the tracks is made by an electromechanical device. The commutation order is given by the cycling system. In absence of power supply, the electromechanical device remains in its position. There is no erasing track by track before the recording, since the recording is made by saturation of the tape.
- Checking : the checking of the recording is made by a systematic reading of the first track, and by "echo-check". The clock is taken out from the biphase signal ; an electronic circuit detects the rate variation of the clock which could occur with an irregular tape motion.

- Technical data

. Size	: $\frac{1}{4}$ ATR short
. Weight	: 5 kg
. Power supply	: 115 V 400 Hz
. Recording medium	: magnetic tape
. Tape length	: 340 meters
. Tape loading	: by cassette
. Tape transport	: continuous type
. Tape speed	: 20 mm/sec.
. Record time	: 75 hours
. Magnetic circuits	: 16 tracks in line, commutated one by one
. Data input rate	: 64 x 12 bits word/sec.
. Format	: biphase (Harward).



EXPLOITATION DES BANDES CRASH ET MAINTENANCE

Processing of crash tapes and maintenance tapes

PROCESSING OF CRASH TAPES AND MAINTENANCE TAPES

The magnetic tapes coming from the digital flight data recorder, or from the maintenance recorder, are mounted on a single device which permits the replay of maintenance tape cassettes, and of DFDR tape cassettes.

The tape speed can be set at 19, 38, 76 cm/sec. The channel selection can be made manually, with a contactor. A complete replay cycle can also be done automatically.

The replayed signal is sent to a bit synchroniser, whose function is :

- to find again the clock rate of the message
- to decide if one bit is a "1" or a "0"
- to transmit the new message to a word synchroniser.

The bit synchroniser supplies the reconstituted clock, it accepts a bit rate included between 10 bits and 2 megabits per second in RZ, NRZL, NRZ, M, O and NRZ M I codes and rates included between 5 and 1 megabits in biphased codes.

The bit synchroniser output is sent to a word synchroniser, the function of which is to ensure the synchronisation of short and long cycles of the PCM message. It enables too the visualization of two parameters selected in the message. Its output enables the message processing.

The message obtained can be :

a) computer processed.

In this case, the message passes through an interconnection module before being sent to a processing unit (computer).

The results presentation can be done :

- on a magnetic tape
- on a high speed printer
- on a plotter
- by CRT display.

b) automatically processed without a computer.

In this case, the word synchroniser output message can be directed :

1) to a tape formatting module which, with help of an associated memory, prepares the information before its passage to a magnetic tape unit, where it is recorded on 7 or 9 channels, in a format compatible with further computer processing.

   A data compression system enables the transmission to the magnetic tape, the only data having variations superior, in absolute value, to a programmable interval, according to the various possible laws.

2) On a data display module, which allows a permanent comparison of various decommutated parameters with maximum and minimum assigned values.

   The maximum and minimum values program either manually or automatically.

3) On an exploitation control module which is used as an interface with :

   - a typewriter
   - a print unit
   - a paper tape punch
   - a module enabling a binary or a decimal display.

c) exploited by immediate display.

In this case, the message is sent onto a selection module which permits the selection of the addresses of a certain number of parameters (16 per module) that one wishes to decommutate in the analogue output unit.

The selection is made on invertor matrix.

The selection module is associated with an analogue display module which enables the display on 16 voltmeters the analogue output of 16 parameters, the addresses of which have just been programmed.

This module uses analogue/digital convertor cards and circuits enabling the balance of the base line and the channels calibration checking.

SD 13 APPLICATION

PROBLEM DEFINITIONS

For the military aircraft concerned, the recording must include :

- the verbal communications picked up on the on-board telephone
- the time
- the differential pressure on two channels
- the static pressure on two channels
- the normal acceleration on one channel
- the heading one channel
- the engine revolutions for each reactor in rev. per minute, two channels
- the consumptions left and right
- hence, 10 input channels sampled.

The autonomy required for commentaries is 30 minutes, and one hour for parameters.

REALIZATION

Three processes were offered for the inscription of the parameters on the tape :

- PCM which offers a high sampling rate, with a large number of parameters and an excellent accuracy ;

- PDM, duration coding requiring also a coding enabling to pass from the analogue signal to the pulse width modulated signal but with performance lower than PCM ;

- PAM has been chosen because, in this case, it is the best fitted because the number of parameters is low and the required accuracy (about 2 %) is not very high ; it offers the advantage of reducing to the minimum the cost of the airborne equipment (suppression of the analogue to digital convertor).

The message so represented by amplitude modulated pulses, its recording on the tape can only be made in frequency modulation because the direct recording processes do not insure a reproduction fidelity of amplitudes sufficient for instrumentation.

The choice of PAM-FM has been conditioned also by the fact that, on ground, it was not necessary to create a flight station confined to the use of the decommutation of airborne recorded tapes, because several agencies in France (CEV and AMD) own material able to receive up to 128 input multiplexed channels, working at a rate between 10 and 4,600 samples per sec.

The proposed recorder, type SD 13, has the following characteristics :

Size	: $\frac{1}{2}$ short ATR (approximate volume : 7.6 dm3)
Mass	: 8 kg without anti-vibration mounts
Power supply	: 28 V DC Standard-Air 2021 D
Consumption	: starting 50 W working 30 W
Presentation of the magnetic frame	: endless loop
Magnetic frame	: tape width 6.35 mm ($\frac{1}{4}$ inch) type PYRAL frame KAPTON, dorsal graphited high temperature ref : CJ 3026
Tape length	: 90 meters
Tape transport	: continuous
Speed	: 1" 7/8
Speed accuracy	: ± 0.5% of the absolute speed
Cumulative flutters	: 2% peak to peak in the 0.3 to 313 Hz frequency range
Tracks number	: 4 or 5
Autonomy	: up to 2 hours (by tracks switching)
Recording mode	: direct voice parameters FM (PAM-FM) PDM PCM.

The parameters are recorded on a closed loop, width 6.35 ($\frac{1}{4}$ inch) and protected from shocks and fire.

The tape autonomy being 30 minutes, the memory of one or two hours is obtained by switching the recording on two or four tracks.

The magnetic heads mounted on the transport plate are as follows : (see photo)

- an erase head : 4 ou 5 tracks
- a recording head : 4 or 5 tracks
- a replay head : 4 or 5 tracks.

This latter circuit is reserved for :

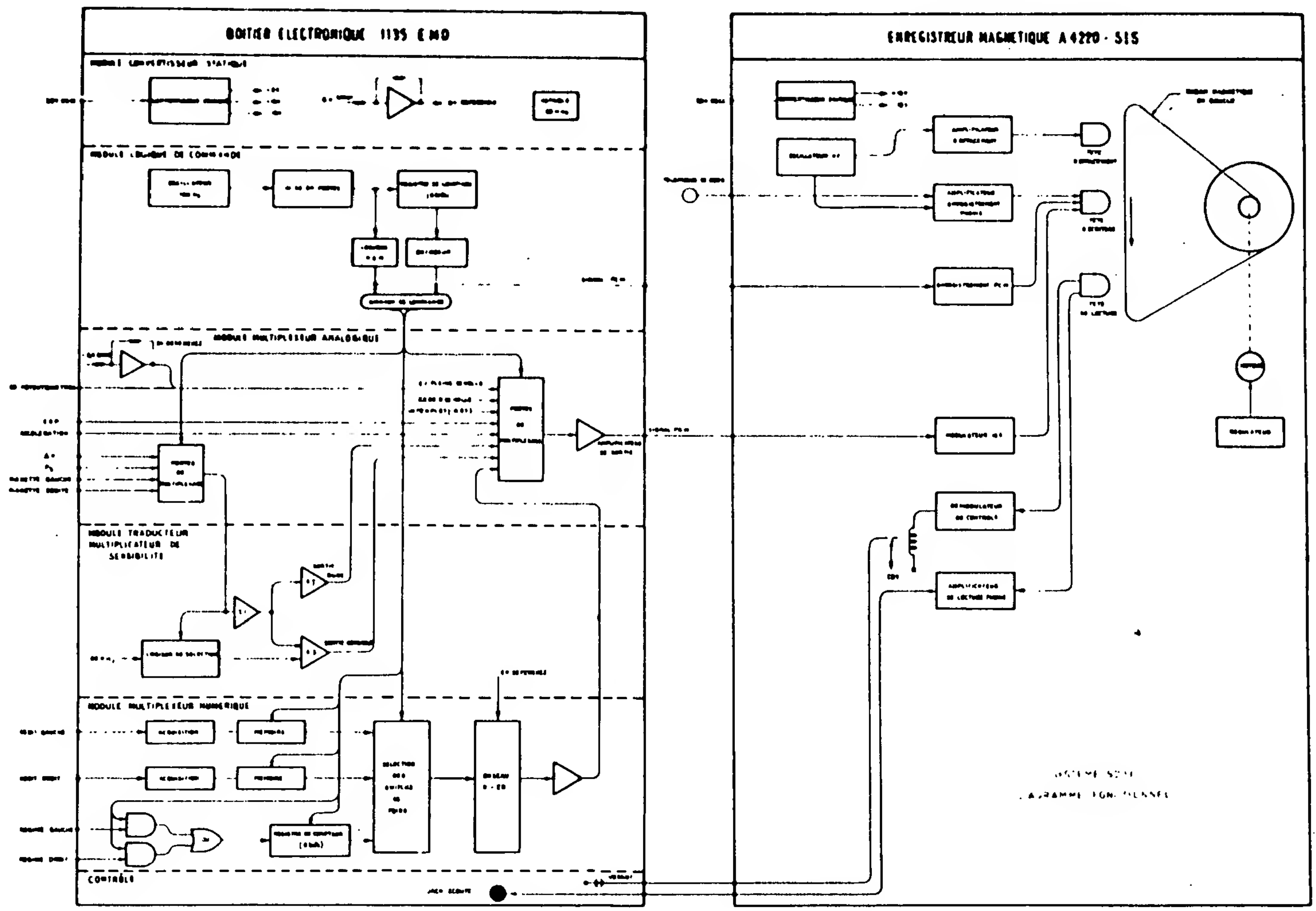
a) the eventual detection of a tape transport malfunction, by permanent replaying of track No. 1.

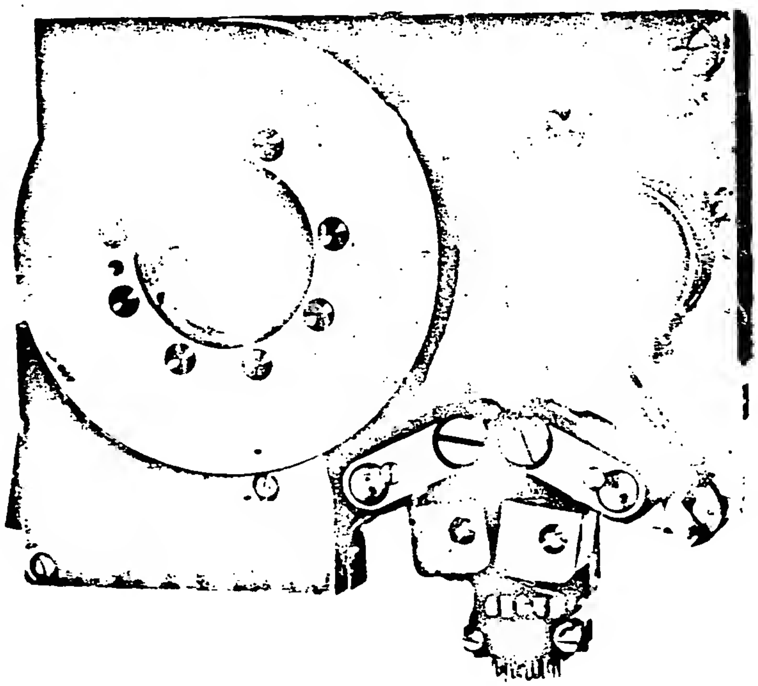
b) the simultaneous and fast replaying of four tracks, in order to recopy the tape.

c) the listening with head-phones of the fifth track (voice).

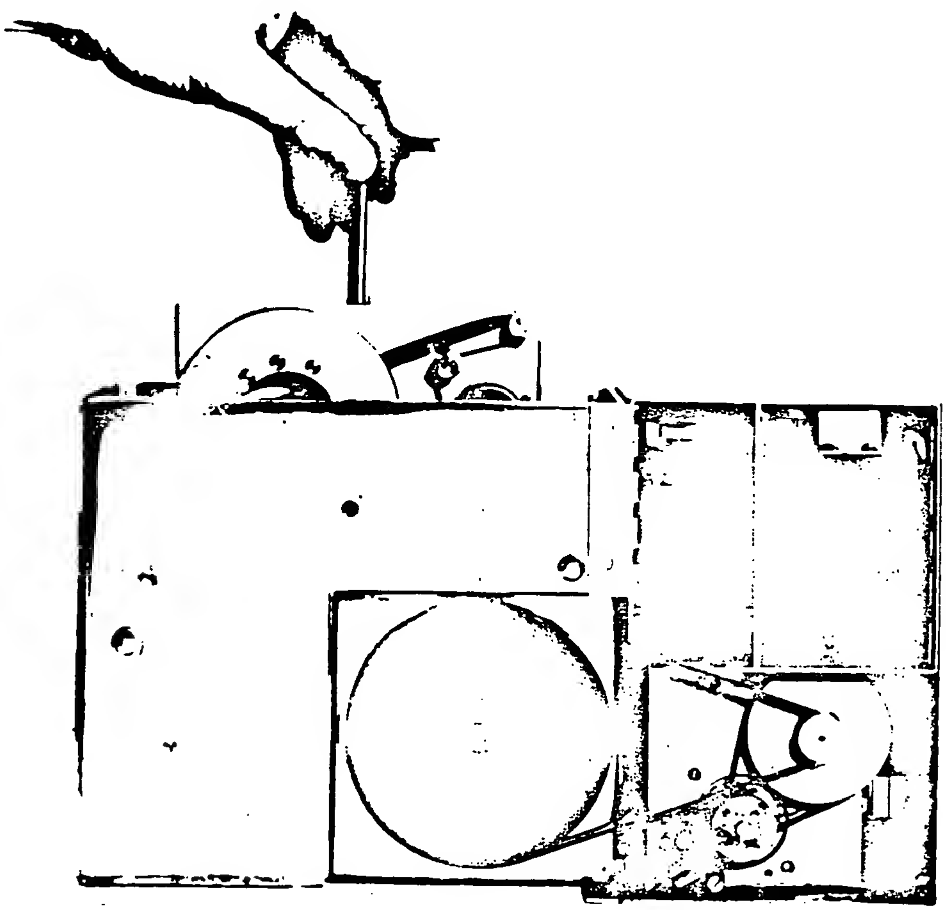
This circuit enables the periodical verification of recordings for checking before or during the flight.

The SD 13 has a shape of a parallelepiped box (see photo), inside of which we can see :


BOITIER ELECTRONIQUE 1135 E ND
MODULE LOGIQUE DE COMMANDE
MODULE MULTIPLEXEUR ANALOGIQUE
MODULE TRADUCTEUR
MULTIPLICATEUR DE
SENSIBILITE
MODULE MULTIPLEXEUR NUMERIQUE
CONTROLE
ENREGISTREUR MAGNETIQUE A 4220 - SIS



Transport plate



a) part of the tape transport, protected against fire, receiving the base plate.

b) the electronics on which are gathered the monitoring and control systems, as well as the plug-in electronics modules (recording, control and replay), with option.

It includes, in its basic version, beyond the transport plate and the tape motion devices :

- the parameters recording amplifier on tracks 1 to 4

- a replay amplifier (parameters) including detection, ensuring the actuation of a replay used to give to the acquisition unit, information on an eventual malfunction tape transport

- a commutation card ensuring :
  - the detection of the track commutation point
  - the switching of the amplifiers on one of the 4 parameters tracks

- the power pack assembly delivering, from the aircraft bus bar, the necessary voltages for mechanisms and for the record and replay electronics

- the regulation assembly of the drive motor.

With option, voice :

- a HF bias amplifier delivering the 270 KHZ frequency necessary for voice recording and for the erase amplifier

- a voice recording amplifier

- an erase amplifier feeding the Ferrite head

- a replay voice amplifier for copy or head-phone monitoring.

The commutation amplifier is wired in such a way that it ensures the inhibition of erasing, in the case of copy or head-phone monitoring.

The transport plate only, on which are mounted the tape, the magnetic circuits and the guide rollers, is mounted in a protected enclosure. The remaining components (drive motor, transmission belts and electronic cards) are fixed in the non protected part of the box.

The tape drive is accomplished by means of two capstans on which the tape is applied by action of two pinch rollers. These capstans (visible at the bottom of the enclosure receiving the plate) are driven by a motor through output pulleys and belts.

On the motor shaft is fixed a tone wheel placed in front of a magnetic head. This tachometric system is used for the motor speed regulation.

TRACK COMMUTATION

A conducting substance applied on a small portion of tape is detected at each passage ; this detection defines a pulse which, through logic, gives rise to the switching of the recording amplifier [illegible]

Each "in use track" is kept in memory by the use of a bistable relay ; the continuity of the recording on this track is then ensured in case of a possible power supply failure or of a stopage of the recorder operation.

LOADING OF THE TAPE - REPLAY OF THE TAPE

The difficulties met during the manual loading of endless loop cassettes as well as the influence of such a loading on the tape transport conditions, lead to the realization of an apparatus conceived to have the following functions:

- to reel, under constant tension, the ¼ inch (6.35 mm) or ½ inch (12.7 mm) magnetic tape

- to transfer the tape, recorded in cassette, to a reel

- to check the normal functioning of the endless loop 6.35 mm (¼ inch) cassettes

- to check the recording, according to the three main methods : direct, frequency modulation, and PCM, of a 6.35 mm cassette, without having to open the loop.

The device has been developed to permit the use of adapters allowing the mounting of any of the principal reels and hubs now on the market.

REALIZATION PRINCIPLE

The apparatus has the shape of a rectangular parallelepiped, inside of which are placed the mechanical assemblies of the tape transport, the commutation, the reproduce electronics and the power supplies.

A plexiglas cover, fixed with knurled screws, ensures the protection of the transport when out of service.

The transport is equipped with a reproduce magnetic head of 4 or 5 tracks.

To realize the proper reeling of a cassette meant working in endless loop, as it is necessary to ensure a constant tension of the magnetic tape.

This problem has been resolved by use of a vacuum chamber and a motor correctly servoed, on a shaft of which is mounted the cassette in a way to give a constant tension, which depends only of the depression in the vacuum chamber. This depression, produced by a pump, is fixed, no setting system being required.

A water manometer directly connected to the chamber enables the checking of the vacuum system.

A system of alternative blocking-up of the cassette still enables a better distribution of the magnetic tape. The take-up motor relation is made by an on-off servo using a photo cell located in the vacuum chamber.

The vacuum lid, fixed with a ball interlocking system, enables to admit the 6.35 mm or 12.7 mm width tapes by merely changing the lid.

DESCRIPTION

a) Figure 1 - Front view

1 - Feed friction
2 - 4220 cassette frame fixation
3 - SD 13 cassette frame fixation
4 - Re-wind upper roller $\frac{1}{4}$"
    Re-wind lower roller $\frac{1}{2}$"
5 - Pinch rollers
6 - Take-up motor
7 - Vacuum chamber
8 - Revolution counter of the take-up reel
9 - On-off invertor
10 - Control keyboard with luminous keys
11 - Photo-cell for tape sensing
12 - Output jack "external LS"
13 - Gain setting of potentiometer for amplifier
14 - Vacuum chamber lid
15 - Incorporated loudspeaker
16 - Power amplifier input jack
17 - Replay amplifiers output jacks
18 - Vacuum indication device
19 - Tape position lamp
20 - Replay security lamp
21 - Replay head
22 - Capstan.

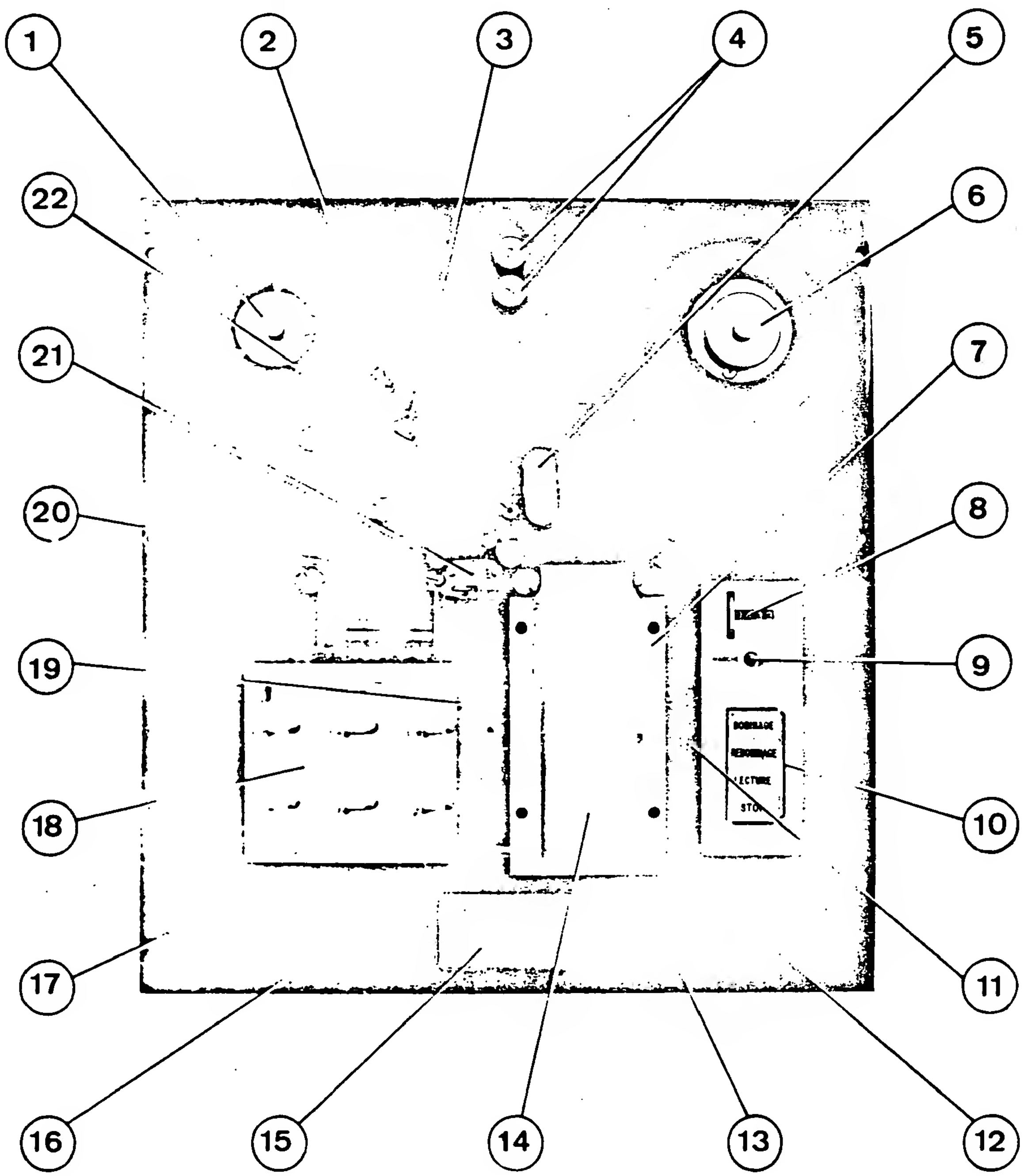


Fig: 1

b) Figure 2 - Inside view

1 - Outphasing capacitor of the take-up motor
2 - Pinch roller control electro-magnet
3 - Take-up motor balance resistor
4 - Central motor balance resistor
5 - Central motor outphasing capacitor
6 - Central motor
7 - Feed friction
8 - Capstan drive pulley
9 - Read amplifiers nest
10 - 24V power supply transistor (2 N 3055)
11 - Regulated power supply + 24 V
12 - Mains transformer
13 - Filtering capacitor
14 - Fan outphasing capacitor
15 - General protecting fuse (0.8 A)
16 - Mains plug
17 - Earth plug
18 - Fan
19 - Capacitor
20 - Capacitor
21 - Power amplifier
22 - ± 18 V power supply
23 - Commutation card
24 - Take-up motor.

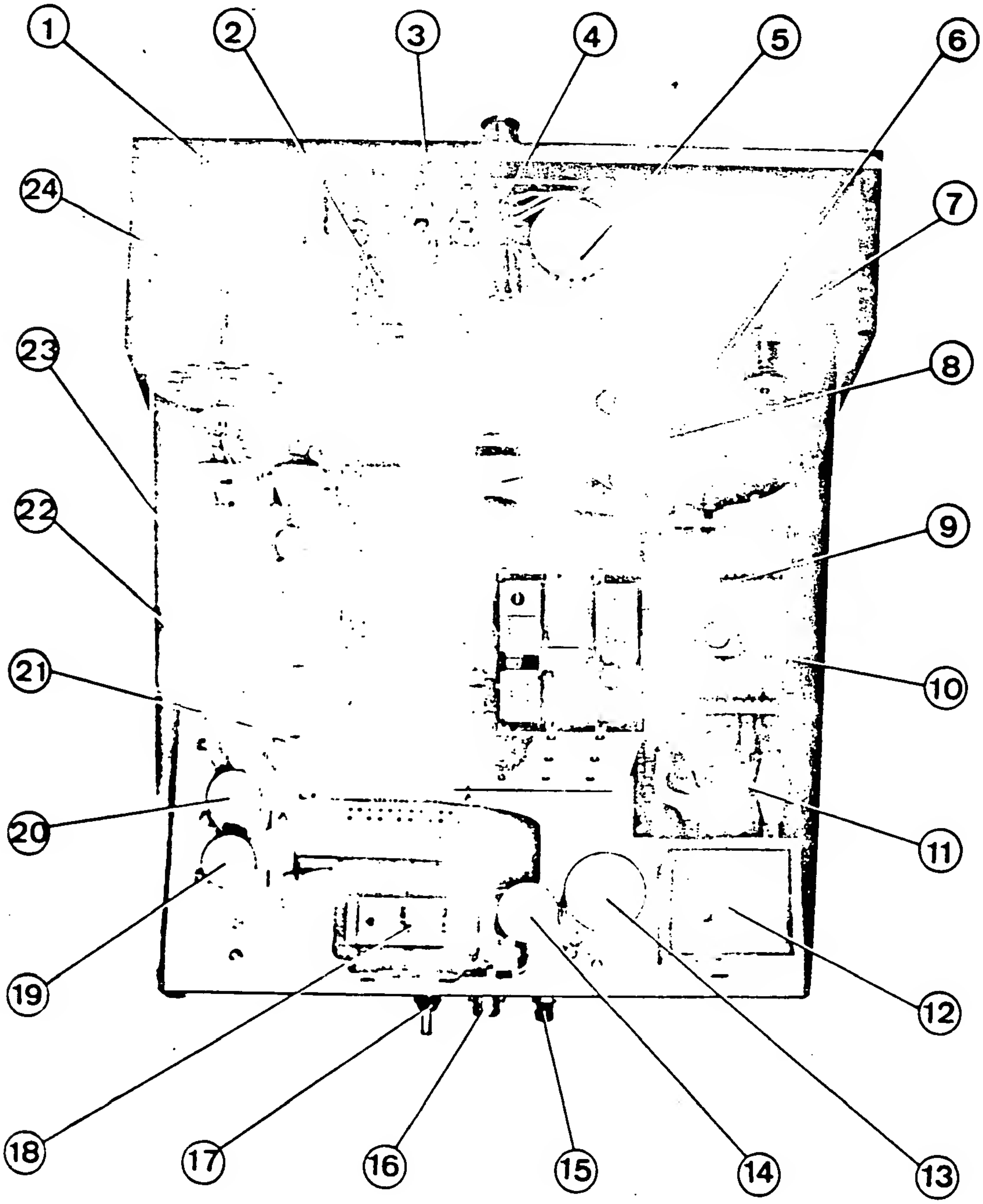
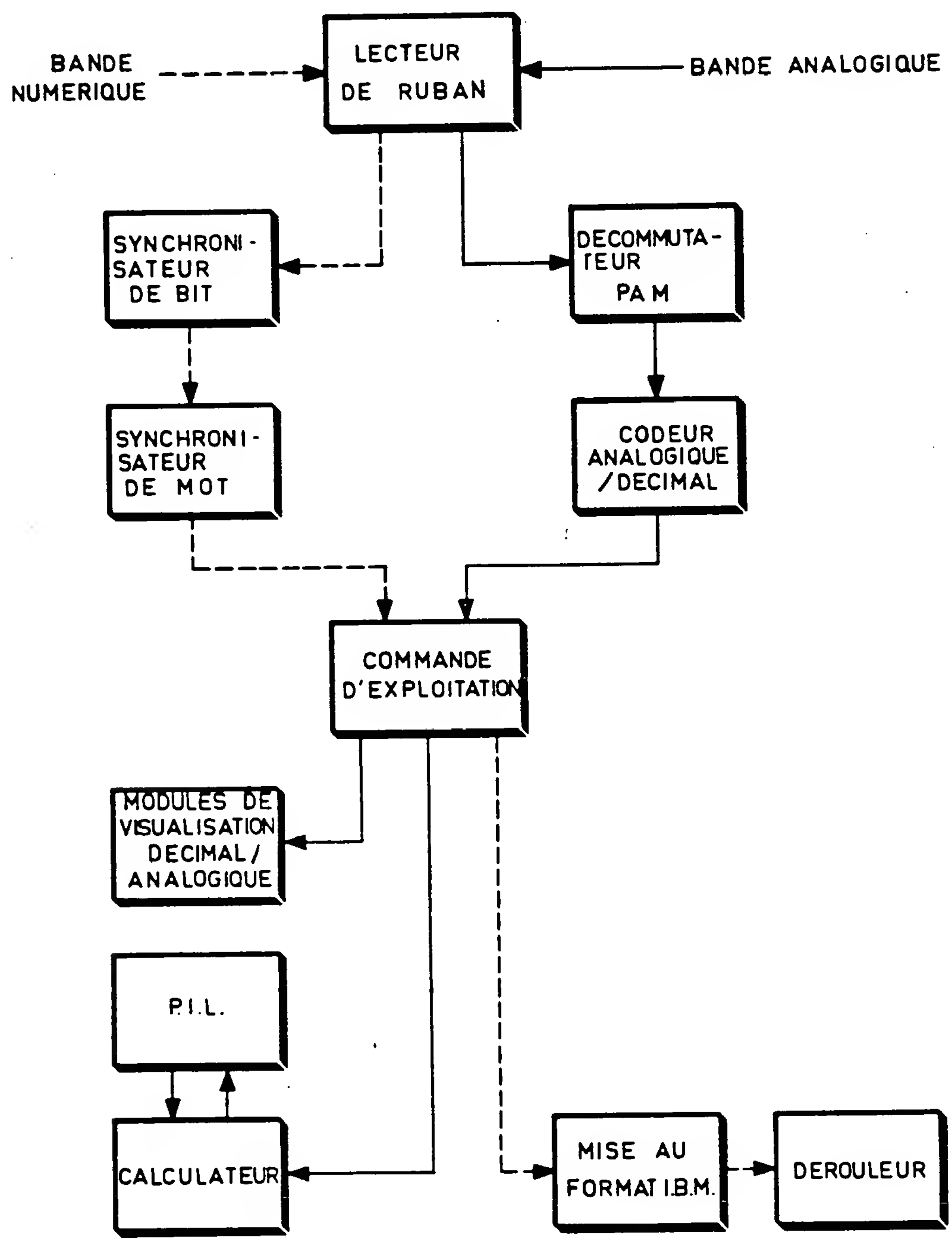


Fig:2



STATION DE DEPOUILLEMENT

Ground station

PROCESSING

The diagram shows an example of a processing station already in service. It consists of the following equipments.

- a tape player which is similar to the type previously described
- a PAM decommutator
- an analogue/digital convertor
- an exploitation control module realizing the computer interface
- a computer associated with a paper punch, printing and playing device.

This unit has a parallel channel including, after the tape replay unit :

- a bit synchroniser
- a formatting module
- a start-stop magnetic tape transport enabling the production of computer compatible tape.

This conception of an automatic equipment enables :

- use for equipment checking
- execution of transducer calibration
- accurate measurements on the system used.

For the processing of tapes recorded on the military aircraft, the station has been used in the following way :

The tape is played on the tape transport previously described and the output signal is sent simultaneously onto the computer analogue input and the decommutator input. The decommutator gives to the computer the bits and frame synchros. On each fixed contact, the computer makes 10 codings of which it carries the medium, the starting moment of the coding is regulated by the decommutator.

The calibration points, maximum 15 per parameter, are used to determine the coefficients of the third degree polynom which are used for correcting values. This kind of station offers the tremendous advantage of presenting automatically the accurate measurements of the system, in applying the scale correcting factors.

RESULTS PRESENTATION

Some interesting flight stages (taking off, supersonic acceleration, end of straight and level supersonic flight, immediately followed by a turn, high speed, low altitude then driving-brakes and 4 g pull out, landing) have been sketched on paper, by means of a plotter.

A listing (see diagram) can be obtained quickly. The X-Y plot shows the three parameters evolution, according to the time :

- normal acceleration.

These graphs have been obtained in replaying the SD 13 magnetic tape recorder.

The transparency superimposed on the X-Y plot represents these same parameters but by manual processing of some points of the diagram from the photographic recorder (type HB).

ACCURACY

The performances which can be realized by such a system are up to the quality of the transducers used. In the flight tests conditions in this case :

- Throttle : the accuracy is sufficient (better than 1%)
- Rev. per mn : the power setting information is stable and accurate within $\pm$ 25 rev. per mn.

  This increment corresponds to a tone wheel pulse for a 1/16 sec. totalizing register. The recording enables to recognise the oscillations affecting the power setting at putting or cutting PC.
- Fuel flows : the resolution is 2 kg. The system works properly.
- Heading : the desired accuracy (1%) is obtained.
- Normal acceleration : the desired accuracy is 1% so 0.16 g. The results are satisfactory.
- Static and differential pressures : the reference system being the HB recorder, it is not possible to make a comparison on a one hour flight. The points plotted show that variations are about 2%.

These comments follow the first flights with airborne SD 13. Results have since been improved by using a channel for the recording of a tape speed compensation signal.

Tests on aircraft with a SD 13 recording system on magnetic tape have shown the advantage of this process compared to the one using a photographic paper.

Though this latter process has for advantage a direct reading of the information, it has drawbacks in operation, such as :

- the need to reach the equipment in order to replace the photo paper at relatively short time intervals.
- the number of parameters which can be recorded simultaneously is rather low.
- it is impossible to record verbal communication.

The magnetic recording has the advantage of being able to keep systematically in memory

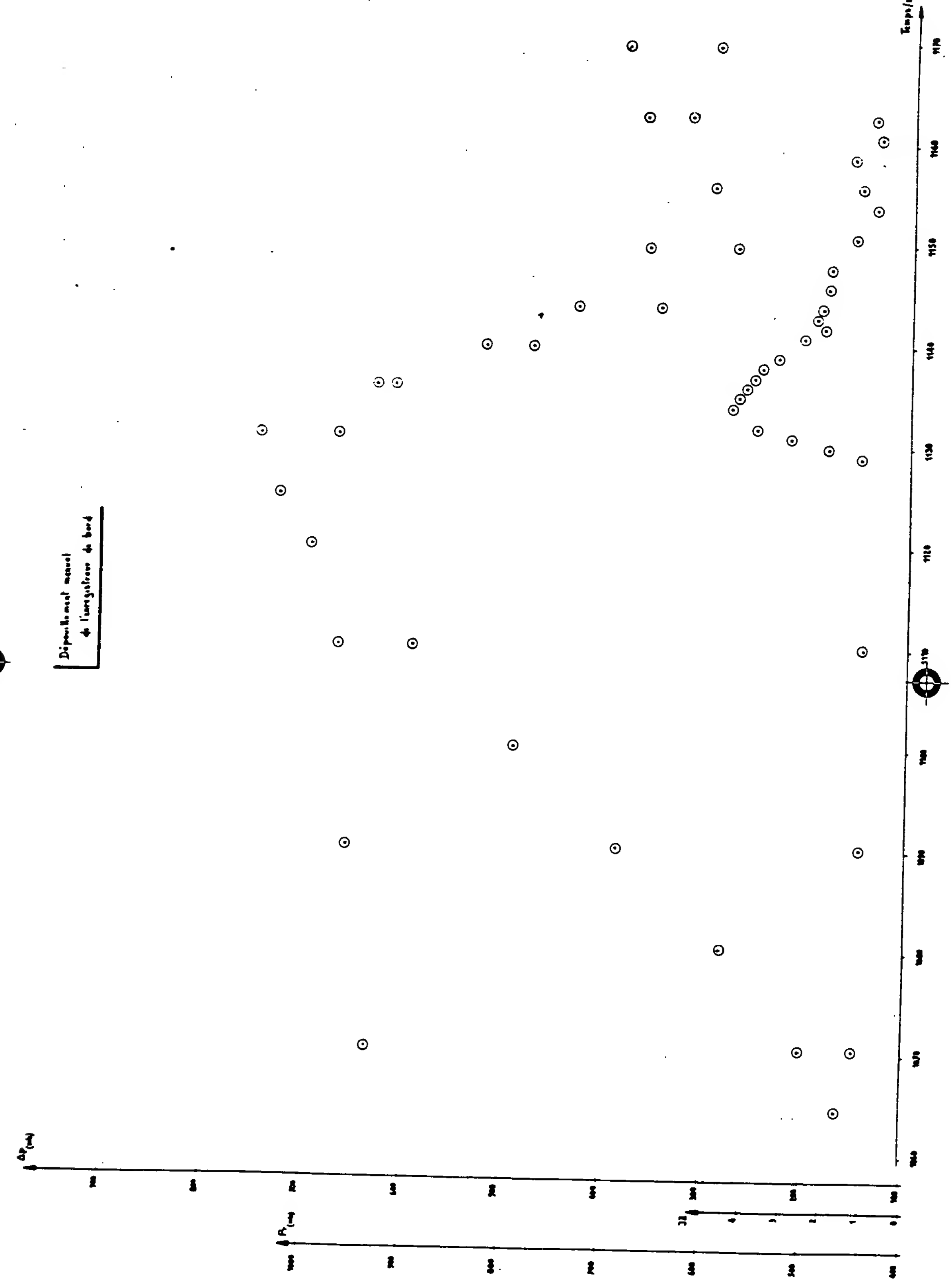
to the increased band pass, it is possible to multiplex the information.

Verbal communications can be recorded and we know their considerable importance during an accident.

At least, the processing times are reduced in important proportions. For argument's sake, a 30 minute flight on which has been picked out a certain number of interesting stages, can be processed with listing and graphs in two hours. The corresponding processing of a photographic recorder mounted in parallel needs more than a day of work.

TEMPS (SEC)	MOTEUR GAUCHE MANET	REGIME (T/MN)	CONS (KG)	MOTEUR DROIT MANET	REGIME (T/MN)	CONS (KG)	CONSOM (KG)	OP GROS (MB)	CONSOM (KG)	OP GROS (MB)	OP FIN (MB)	PS GROS (MB)	PS FIN (MB)	JZ (G)	CAP (DG)	MINI	MAXI
507.58	54.8	0 2	284	21.6	8393 0	82	366	5.	366	5.	2.31	1003.	1008.67	0.98	130.3	-2393	3963
507.83	54.1	0 0	284	21.2	8393 0	82	366	-2.	366	-2.	1.64	1010.	1008.78	0.87	125.9	-2328	3939
508.08	54.8	0 0	284	21.9	8393 0	82	366	8.	366	8.	2.16	1007.	1009.20	1.19	134.4	-2417	3931
508.33	54.6	0 0	284	21.2	8418 0	82	366	-1.	366	-1.	1.78	1002.	1008.99	1.02	128.5	-2379	3954
508.58	54.9	0 0	284	21.5	8393 0	82	366	-3.	366	-3.	2.38	1002.	1008.96	0.99	133.4	-2396	3955
508.83	53.9	0 0	284	20.7	8418 0	82	366	1.	366	1.	0.66	1000.	1007.96	0.91	128.1	-2345	3972
509.08	54.2	0 0	284	20.9	8393 0	82	366	12.	366	12.	1.51	1006.	1008.86	1.03	128.8	-2350	3953
509.33	54.0	0 2	286	20.9	8393 0	82	368	1.	368	1.	1.62	1000.	1008.50	0.96	129.9	-2374	3968
509.59	54.0	0 0	286	21.2	8393 0	82	368	0.	368	0.	1.88	1007.	1009.24	1.02	129.2	-2349	3930
509.84	54.4	0 0	286	21.9	8393 0	82	368	-7.	368	-7.	2.50	1005.	1008.90	1.01	127.7	-2356	3951
510.09	54.5	0 0	286	20.4	8393 0	82	368	0.	368	0.	1.32	1001.	1009.08	1.03	130.0	-2348	3946
510.34	54.3	0 0	286	21.1	8393 0	82	368	-6.	368	-6.	1.68	1002.	1008.12	1.00	128.6	-2370	3962
510.59	54.7	0 0	286	21.0	8418 0	82	368	-0.	368	-0.	3.66	1005.	1009.61	1.02	132.3	-2377	3932
510.84	54.4	0 0	286	20.4	8393 0	82	368	2.	368	2.	1.39	999.	1008.38	0.98	129.9	-2350	3958
511.09	54.7	0 2	288	21.9	8418 0	82	370	-2.	370	-2.	2.19	1007.	1008.93	1.03	131.8	-2375	3934
511.34	55.1	24 0	288	21.9	8418 0	82	370	18.	370	18.	3.79	998.	1009.39	1.10	136.1	-2471	3968
511.59	54.6	0 0	288	20.8	8393 0	82	370	14.	370	14.	2.93	1000.	1008.94	0.96	128.7	-2412	3970
511.84	53.9	0 0	288	21.1	8393 0	82	370	11.	370	11.	2.12	1007.	1009.06	1.12	131.5	-2381	3946
512.09	54.2	0 0	288	20.4	8393 0	82	370	-7.	370	-7.	0.74	1002.	1008.64	0.99	126.6	-2307	3951
512.34	54.4	0 0	288	20.8	8393 0	82	370	-1.	370	-1.	2.77	1005.	1008.31	1.12	129.9	-2376	3947
512.59	54.3	0 0	288	20.8	8393 0	82	370	7.	370	7.	2.30	1003.	1008.33	0.91	130.4	-2359	3961
512.85	54.7	0 2	290	21.5	8418 0	82	372	11.	372	11.	2.70	1004.	1009.07	1.11	128.8	-2408	3938
513.10	54.6	0 0	290	21.5	8418 0	82	372	0.	372	0.	1.64	1008.	1008.28	0.92	126.5	-2369	3950
513.35	54.1	0 0	290	21.2	8393 0	82	372	-5.	372	-5.	2.13	1004.	1009.01	0.96	129.2	-2342	3948
513.60	54.8	0 0	290	21.5	8418 0	82	372	6.	372	6.	3.11	1002.	1009.07	1.10	131.5	-2428	3953
513.85	53.7	0 0	290	21.0	8418 0	82	372	0.	372	0.	0.67	1005.	1009.13	0.90	127.0	-2341	3951
514.10	54.2	0 0	290	20.3	8418 0	82	372	-4.	372	-4.	0.72	1004.	1008.85	1.04	128.2	-2324	3947
514.35	54.7	0 0	290	20.7	8393 0	82	372	2.	372	2.	2.12	1006.	1008.92	1.12	129.9	-2367	3930
514.60	53.8	0 2	292	20.9	8393 0	82	374	-4.	374	-4.	1.60	998.	1008.75	0.98	127.6	-2348	3956

Typical listing



X-Y plot with HB